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The performance of research joint ventures in boosting R&D activities in the presence of knowledge spillovers

Bachelor Thesis in Economics

Author: Matilda Saarinen
Opponent: Tommi Kovero
Instructor: Pauli Murto

ABSTRACT

Firms conduct R&D continuously to develop new products and increase efficiency through cost-reductions. Due to knowledge spillovers, the private firms are not incentivized to conduct enough research from the social standpoint. There exist three main types of public policies to incentivize R&D: taxes and subsidies, intellectual property rights and R&D cooperation. This thesis a literature review that applies the famous d'Aspremont-Jacquemin –model and related economic studies to show that R&D cooperation in research joint ventures helps to not only increase the incentives to research by internalizing the spillover externalities but also eliminate excessive duplication in research, increase efficient knowledge sharing, pool risks and maintain continuity in building up the national competitiveness. Other R&D policies may fix the biased incentives but fail to bring about these additional benefits. Even though R&D cooperation is proven to be a beneficial public policy both in theory and with successful real-life ventures, potential threats exists and special scrutinizing must be conducted to prevent collusion and increased monopoly power in the product market.

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1. INTRODUCTION

When a private firm produces new knowledge in its research facilities, the new information is used inside the firm to develop new products or produce the current ones more efficiently (Katz & Ordover, 1990). What might be left unobserved without the help of economic theories is that part of this knowledge might transfer to surrounding rival firms even though no official exchange is made. This economic phenomenon is called a knowledge spillover. (d'Aspremont & Jacquemin, 1988).

Knowledge spillovers are positive externalities of knowledge production because they benefit the whole society by eliminating duplicative efforts and inducing more productive innovation activities (Katz & Ordover, 1990). However, this means that individual firms cannot fully restrict competing firms from taking advantage of the research results to develop new products or enhance their efficiency (Choi, 1993). This inability to appropriate the benefits of R&D results lowers firms' motives to conduct own research (Suzumura, 1992). In general, private R&D incentives are fundamentally biased from the socially optimal ones because individual firms maximize profits and ignore the welfare externalities (Katz & Ordover, 1990).

While the biased private incentives are widely recognized in economic studies dealing with R&D activities, there are also various public policies aiming to correct them. There exist three main types of policies: tax and subsidy policies, ex post cooperation policies including intellectual property rights such as patents and licenses, and ex ante cooperation policies allowing cooperative agreements between firms to share their costs and R&D outputs (Katz & Ordover, 1990). These R&D cooperation arrangements are generally called research joint ventures in economic studies.

Discussion around R&D cooperation and innovation practices in general has been boosted by the years of decelerated growth after the financial crisis. The newest applauded concept is public-private partnerships (PPP) that are a form of research joint ventures. There exist several highly successful PPPs around the world such as a venture called DIMECC in Finland. (OECD, 2017). Motivated by demonstrated success of research joint ventures, this thesis focuses on how R&D cooperation can enhance the firms' motives to engage in R&D and the overall productivity of R&D in the presence of spillovers.

The results from various studies show that research joint ventures play a central role in fixing research incentives, increasing R&D levels and eliminating excessive duplication especially in industries with high spillovers and intense competition. These benefits are further intensified with the synergy benefits gained by information sharing and resource pooling. Additionally, research joint ventures allow risk pooling and continuity in research in the long-term. However, cooperation in the research joint ventures must be strictly limited to only research because cooperation in the production side might bring on collusion and monopoly power.

The comparative analysis with other public policies shows that even though every policy can manage to fix the research incentives, subsidies and intellectual property rights fail to bring about the additional benefits for boosting R&D activities. In addition, the subsidies may inflict moral hazard and deadweight losses on other actors whereas the intellectual property rights induce efficiency losses by disseminating knowledge at socially too high prices. Most importantly, these alternative policies perform worse than R&D cooperation in motivating knowledge sharing and maintaining continuous research efforts that support competitiveness and long-term economic growth.

1.1. Research question and method

Knowledge spillovers are inescapable for any firm engaging in R&D activities which means that firms must take them into account in their decisions as profit-maximizing actors. In this thesis, I examine how spillovers affect the equilibrium amounts of R&D. It is in specific interest to examine the theories behind the evolution of R&D levels when firms engage in cooperation in research joint ventures. Since the private incentives of R&D work are recognized biased from the socially optimal ones, I compare those two and explain the differences. I also broaden my analysis to cover different aspects of spillovers and R&D cooperation to gain a more comprehensive picture of the performance of research joint ventures in boosting R&D. Lastly, I compare R&D cooperation with other public policies, such as subsidies and intellectual property rights, to see how research joint ventures perform relatively better.

This thesis is a literature review on the famous d'Aspremont-Jacquemin –model and other supporting theories examining spillovers and the performance of R&D cooperation in their

presence. The literature on this topic is very diverse and applies very different approaches which is why it might be difficult to combine the multiple theories and draw conclusions. Therefore, the main input of this thesis is to clarify the main theory findings and provide clear explanations for the interaction of spillovers and R&D cooperation. I take advantage of the multiple features provided by different studies to present a diverse analysis of how this interaction adjusts in different situations.

1.2. Previous research

The model of d'Aspremont and Jacquemin (1988) is groundbreaking in the sense that it initiated a great amount of studies and theoretical models of R&D cooperation. Many authors develop the d'Aspremont-Jacquemin -model further by adding features for more elaborate analysis. Suzumura (1992) engages in more extended welfare analysis whereas Vonotras (1994) adds features for different research types and venture structures. Cooperative agreements can allow different degrees of competition and coordination in both research and production and the welfare effects of different arrangements are presented by Kamien, et al. (1992). Beath, et al. (1998) focus on the information sharing in research joint ventures and Choi (1993) connects R&D cooperation to product market competition. In addition, Jacquemin (1988) uses the model's results to offer various additional aspects for cost-benefit analysis and policy decisions regarding R&D cooperation.

A wide range of economic literature focuses on R&D competition and performance already before the publication of d'Aspremont-Jacquemin –model which presents a strategic commitment game. Katz (1986) uses a four-stage model to study the social benefits of R&D cooperation relative to the degree of product market competition as well as the feasible cost and research output sharing. Patent race models are an alternative way of measuring the effects of research cooperation. For example, Grossman and Shapiro (1987) use a patent race to model how firms compete and cooperate in R&D. Spence (1984) builds his own model to examine the performance of R&D work in reducing costs and focuses on the importance of efficient sharing of knowledge.

The studies presented above build their analysis around a specific model. Wider perspectives are provided for example by Katz and Ordover (1990) who gather different aspects R&D

cooperation, compare it to other R&D policies and finally apply the theories to real-life cases of research join ventures. As for De Bondt (1996), various types of theoretical models are analyzed and special attention is paid to the relevant characteristics of knowledge spillovers. In addition to all the presented studies, there exists an endless number of other studies with slightly different aspects. I have chosen the studies to this thesis based on their coherence with my research question which may have required excluding some important studies. I present my suggestions for future research from these other studies in the conclusions.

1.3. Structure

The thesis continues as follows: The next section briefly clarifies the key terms used in the review. The section III presents the key model of this thesis, analyses its results by applying various economic theories and presents a critical assessment of the model's interpretation of knowledge spillovers and R&D cooperation modeling. In the section IV, I aim to explain what are the advantages and disadvantages of R&D cooperation as a policy measure and how it performs relative to other R&D policies. Finally, the section V puts all pieces together.

2. KEY TERMS

The economic literature studying knowledge spillovers and R&D activities uses slightly different terms to describe these phenomena. Therefore, it is crucial to describe in detail the terms used in this thesis. Here the essential terms are combined from several studies and the goal is to generalize the theories under clear definitions.

2.1. Knowledge spillovers and appropriability problem

Knowledge spillovers mean that part of the technological information produced by one firm's R&D activities transfers to other firms, either as an involuntary leakage or a voluntary exchange (De Bondt, 1996). The information can transfer via various channels such as patens disclosures, publications, conversations between employees of different firms or hiring of employees of the innovator (Mansfield, 1985). In this one-way transfer, the information moves between these firms without any payment made in exchange (d'Aspremont & Jacquemin,

1988).

Knowledge spillovers are a crucial issue in R&D activities because they inflict the appropriability problem for individual firms, meaning that the firms cannot restrict the benefits of research spilling over to competing firms (Choi, 1993). This problem inflicts the decrease of individual firms' incentives to conduct research and most importantly, distorts them from the social incentives (Suzumura, 1992). In addition to knowledge spillovers, unbeneficial government policies and loose property rights are examples of other sources of divergence between private and social incentives (Katz & Ordover, 1990). However, my analysis focuses solely on the phenomenon of knowledge spillovers.

In total, technological knowledge includes incomplete and poorly defined know-how that is hard to utilize (Vonotras, 1994). Therefore, an important detail is that knowledge spillovers particularly cover the useful part of the technological information. As R&D activities are meant to enhance efficiency and thus reduce costs, the knowledge spillovers benefit the receiving firms as well through cost reductions. (De Bondt, 1996). Consequently, spillovers are usually symbolized by a coefficient β in the production cost function. This coefficient is interpreted as the proportion of produced knowledge that spills over and gets values from 0 and 1. (see e.g. d'Aspremont & Jacquemin, 1988). The presentation of d'Aspremont-Jacquemin –model in section 3 explains in detail how spillovers are included in the decision formulations.

2.2. Research joint ventures

The economic literature uses a variety of terms, such as R&D cooperation or ex ante R&D cooperation, when modeling the research joint ventures. Throughout this thesis, I use the term R&D cooperation for the theoretical modeling and for referring to the policy measure. The term research joint venture is used for referring to the entity of cooperating firms as well as the broad term of the examined phenomenon. Cooperative efforts and levels are the inputs and outputs that research joint ventures produce.

R&D cooperation in research joint ventures are one form of public policy for enhancing innovation activities (Katz & Ordover, 1990). The cooperative models of research joint ventures vary from developing certain technology or product together to multi-member

ventures conducting general research that benefits equally all participant firms (Vonotras, 1994). However, the fundamental social objective is always the same: enhance productivity in research by sharing information and coordinating research paths (Beath, et al., 1998). For individual firms, research joint ventures mean sharing costs and increasing efficiency in R&D work (Katz, 1986). The cooperation also allows attaining synergy benefits, maintaining continuity in research and pooling risks related to R&D work (Douglas, 1990). The organizational mechanisms and the characteristics of cooperating firms arguably affects how effectively a research joint venture operates and how strong benefits are obtained (Katz & Ordover, 1990).

R&D cooperation setting in this thesis is applied from the model of d'Aspremont and Jacquemin (1988) where two firms share basic information and efforts in the R&D phase before product-market competition. The model doesn't describe any characteristics or cooperative mechanisms in detail which makes it a very simplified version of a real-life situation. On one hand, this feature makes the model an excellent instrument for explaining how R&D cooperation and spillover effects work but on the other hand, it brings on the need for careful analysis outside the model. I explain the central deficiencies of the model in section 3.4. and engage in deeper analysis in section 4.

3. D'ASPREMONT-JACQUEMIN MODEL

The famous model of d'Aspremont and Jacquemin forms the theoretical background of this thesis. In this section, I explain the mathematical logic behind the model and the computation of the different equilibrium levels of R&D. The last two parts engage in analyzing the results based on other economic studies and the deficiencies of the simplified model.

3.1. Introduction

d'Aspremont and Jacquemin (1988) represent a two-stage duopoly strategy game where the firms choose levels of R&D in the first precompetitive stage and levels of production in the second competitive stage. Throughout the model, the firm's own decisions are marked with index i whereas the other firm's decisions with index j. There are two firms in a duopoly which

means that $i = 1, 2$.

The model analyzes three levels of cooperative effort: no cooperation, cooperation in R&D and complete two-stage cooperation in both R&D and production. The last setting is left out of the analysis as the focus in this thesis is only on the linkage between spillovers and R&D work. When firms cooperate in research in the first stage, they engage in joint profit maximization and are symmetric, i.e. invest same amounts to R&D.

The authors model the first-stage profit functions for the two competing companies, which they can then use to define the equilibrium for each level of R&D cooperation. To get to the first-stage profit function, the second-stage profit function and the consequent equilibrium output is needed. They start by defining the linear inverse demand function D^{-1} as well as the linear cost function C_i. The cost function takes into account the current technology level A, firm's own investment level x_i and the other firm's investment x_j multiplied by spillover rate β. Both investment levels are negative factors due to their cost reducing character. The functions are defined as follows:

$$D^{-1} = a - bQ$$
$$C_i = (A - x_i - \beta x_j) q_i.$$

In the second-stage product-market competition, the profit function of firm i embodies the total income element $D^{-1}Q$, the total production costs C_i and the cost of installing the current investment level x_i, defined by $\gamma \frac{{x_i}^2}{2}$ (Henriques, 1990). As assumed along this thesis, the spillover rate β affects the profits through the production costs. The *second-stage profit function* can thus be written as:

$$\pi_i = (a - bQ) q_i - (A - x_i - \beta x_j) q_i - \gamma \frac{{x_i}^2}{2}.$$

The model represents functional forms for non-cooperative, cooperative and socially efficient levels of R&D that are deduced from first-stage profit functions of each setting. In addition to profit maximization behavior, the model assumes that the equilibrium production level q_i chosen by firms in the second stage is a unique and efficient Cournot-Nash equilibrium. When

the function of q_i is introduced in either the individual firm's second-stage profit function π_i defined above, the resulting function represents the *first-stage profit-maximization problem* π_i^* as a function of own investment x_i and the other firm's investment x_j.

Solving this problem for firm i, the efficient level of R&D is obtained. The amount is a unique equilibrium result satisfying $\frac{\partial \pi_i^*}{\partial x_i} = 0$, meaning that it is obtained when profits are maximized. The functional forms for each setting computed by d'Aspremont and Jacquemin (1988) are introduced separately in the following section.

3.2. Different levels of R&D

3.2.1. Non-cooperative

In the first-stage of the non-cooperative setting, the duopoly firms maximize their individual profits. The profit of firm i in the first-stage is written as:

$$\pi_i^* = \frac{1}{9b}\left[(a - A) + (2 - \beta)x_i + (2\beta - 1)x_j\right]^2 - \gamma\frac{{x_i}^2}{2}.$$

Consequently, the equilibrium result for x_i obtained from $\frac{\partial \pi_i^*}{\partial x_i} = 0$ is

$$x_i^* = \frac{(a - A)(2 - \beta)}{4.5b\gamma - (2 - \beta)(1 + \beta)}.$$

3.2.2. Cooperative

In the cooperative setting, the duopoly firms agree on a symmetric R&D investment $x_1 = x_2 = \hat{x}$ and engage in joint profit maximization in the first stage. The joint profits are calculated simply as (see the complete function in d'Aspremont and Jacquemin (1988, p. 1135))

$$\hat{\pi} = \pi_1^* + \pi_2^*$$

and the equilibrium cooperative R&D level solving $\frac{\partial \hat{\pi}}{\partial \hat{x}} = 0$ is

$$\hat{x} = \frac{(a - A)(1 + \beta)}{4.5b\gamma - (1 + \beta)^2}.$$

When comparing the formulation of the non-cooperative and cooperative equilibrium amounts, the crucial factors are $(2 - \beta)$ and $(1 + \beta)$. These factors are the only channels through which spillover rate β affects the equilibrium amounts. The fact that $(2 - \beta) > (1 + \beta)$ when $\beta < 0.5$ and $(2 - \beta) < (1 + \beta)$ when $\beta > 0.5$ explains the order of magnitude between x^* and $\hat{x}$ with small and large spillovers.

3.2.3. Social optimum

The social welfare function in the model offers an efficiency standard to analyze the results of the non-cooperative and cooperative settings. The *social welfare function W of consumption Q* is naturally the sum of the consumer surplus $V(Q)$ and the producer surplus obtained as the sum of the production costs C and the cost of installing the investment level γx^2:

$$W(Q) = V(Q) - AQ + (1 + \beta)xQ - \gamma x^2.$$

Computing the welfare maximizing level of Q resolving $\frac{\partial W(Q)}{\partial \mathrm{Q}} = 0$ in the second stage, and placing it to the first-stage social welfare function $W^{**}(Q) = W(Q)$, the model obtains the socially efficient level of R&D satisfying $\frac{\partial W^{**}}{\partial \mathrm{x}} = 0$:

$$x^{**} = \frac{(a - A)(1 + \beta)}{2b\gamma - (1 + \beta)^2}.$$

The only factors that distinguishes the formulation of the social optimum amount from the cooperative one is the numeral coefficient before $b\gamma$. The fact that 4.5 > 2 ensures that x^{**} is always higher than $\hat{x}$. The formulations of social optimum and non-cooperative amounts differ also regarding the appearance of either the factor $(1 + \beta)$ or $(2 - \beta)$ in the numerator and the denominator. However, 4.5 as a coefficient of $b\gamma$ ensures that x^* is always smaller than x^{**}.

The model can be criticized for forcing optimal prices to equal marginal costs in the market which naturally affects the resulting R&D level in the social optimum. The applicability of this optimum can be questioned because attaining that level would need intervention by government which doesn't agree with democratic governance. (Suzumura, 1992). Suzumura (1992) introduces a feasible second-best optimum to escape this problem, but the results are not different from the ones introduced in the next section. Therefore, I assume that the applicability of the social optimum doesn't affect the relevant conclusions of this thesis.

3.2.4. Summary

Comparing the results in section 3.2.1.-3.2.3, d'Aspremont and Jacquemin (1988, 1990) obtain the following classification: When spillovers are large ($\beta > 0.5$),

$$x^{**} > \hat{x} > x^{*}$$

and when spillovers are small ($\beta \leq 0.4$),

$$x^{**} > x^{*} > \hat{x}.$$

The results show that when spillovers are small, the non-cooperative R&D level is higher than the cooperative one. On the contrary, the cooperative R&D level exceeds the non-cooperative one when spillovers are large. Even though this model is a very simplified description of the real world, these results illustrate the effects that cooperation has on R&D activities. In the next section, I provide explanations for these results based on the theories presented in the economic literature.

3.3. Analyzing the results

The starting point in the analysis of d'Aspremont and Jacquemin (1988) is that R&D cooperation reduce R&D levels because firms share their research results and can eliminate useless duplicative efforts in their research agendas. However, they ignore the fact that cooperation has incentive enhancing effects as well that increase R&D levels (Jacquemin,

1988). A central issue regarding spillovers is that the competitors can use the R&D information without paying for it which limits the competitive advantage of the innovator (De Bondt, 1996). This inability to fully appropriate the gains from individual R&D work lowers private incentive to conduct research (Suzumura, 1992). Cooperation helps to internalize the knowledge spillovers and their positive externality effects, which serves as a mechanism to restore incentives (Katz, 1986). The relative magnitude of these opposite effects depends on the magnitude of spillovers.

When spillovers are small, the results of d'Aspremont and Jacquemin (1988) indicate that non-cooperative level of R&D is superior to the cooperative one. The lower level of cooperative R&D is partly explained by the reduced duplication of research efforts (Katz, 1986). In this case, the appropriability problem of knowledge production is alleviated because rivals gain smaller cost reducing benefits due to lower spillover rates (Suzumura, 1992). Consequently, the competitive advantage of individual R&D work and hereby the individual R&D levels aren't skewed downwards (De Bondt, 1996). In addition, individual firms may put socially excessive efforts to R&D simply to gain advantage over the competitors by investing more (Brander & Spencer, 1983). These theories support the model's results for small spillovers.

On the contrary, large spillovers magnify the appropriability problem related to R&D work as more technological information spills overs to other firms (De Bondt, 1996). Therefore, the individual R&D incentives are reduced significantly and cooperation plays an important role in restoring incentives by internalizing the benefits of knowledge spillovers (Suzumura, 1992). Cooperation also allows increasing efficiency in research through cost-sharing which further increases the incentives (Katz, 1986). These theories support the results of d'Aspremont and Jacquemin (1988) which indicate that cooperative R&D levels exceed the non-cooperative ones when spillovers are large.

In the socially optimal situation, the d'Aspremont-Jacquemin –model maximizes the total welfare as a function of the consumer and producer surpluses. This definition already separates the socially efficient R&D level from the private levels that are defined by firms' profit-maximization. Private profit-maximization means that private firms ignore the welfare effects of their actions on other actors (Katz & Ordover, 1990). These welfare effects arise because new knowledge can benefit other firms by increasing the profits through the cost-savings that it enables (De Bondt, 1996). As the cost-savings increase the producer surplus, new R&D

information allows increasing the total surplus and welfare in the economy (Katz, 1986). Therefore, private firms ignoring these positive welfare externalities conduct too little research from the social standpoint (Katz & Ordover, 1990). These theories support the model's results indicating that the socially efficient level of R&D always exceeds the private levels.

As a conclusion, the results show that the effect of reduced duplication dominates the incentive effects when spillovers are small and therefore the cooperative R&D levels remain small. On the contrary, large spillovers emphasize the incentive effects increasing the cooperative R&D levels compared to the individual ones and the reduced duplication is compensated. However, neither the cooperative nor the non-cooperative R&D amount exceeds the social optimum at any level of spillovers.

3.4. Analyzing the model

It is important to remember that the d'Aspremont-Jacquemin model is a very simplified presentation of the research joint ventures and therefore, it might fail to fully demonstrate all properties of cooperation. In this section, I extend my analysis of the model by including important features related to the spillovers and modeling R&D cooperation. The idea is to provide a more comprehensive examination of the effects of cooperation and describe both situations where the beneficial effects are emphasized and reasons why cooperation might in fact be unfavorable.

3.4.1. Interpretation of knowledge spillovers

The economic literature studying knowledge spillovers has identified several characteristics that complicate the modeling of R&D activities. Knowledge in general is a combination of poorly-defined know-how and highly-codified information which makes it hard to utilize knowledge effectively (Vonotras, 1994). Hereby, the first important feature of knowledge spillovers is that they particularly cover the useful part of the technological knowledge produced by R&D work. The magnitude of these useful elements depends on the similarities in firms' existing technologies. Therefore, the ability to take advantage of the new information varies significantly across different firms. (De Bondt, 1996). In addition, individual R&D work affects the firm's abilities to identify and exploit the knowledge that spills over from the

surrounding firms (Cohen & Levinthal, 1989). d'Aspremont-Jacquemin –model presents spillovers simply by some rate β which leaves it for additional analysis to take account of possible asymmetries that affect the real magnitude of spillovers.

Second important aspect is that d'Aspremont-Jacquemin model allows analyzing cooperation only in generic research. This may create problems for more general analysis since competition in R&D activities occurs in both generic and development research. Similarly, firms can choose to cooperate in either of these research types. (Grossman & Shapiro, 1987). In truth, most firms conduct both types of research individually or cooperatively in different joint ventures at the same time. Among these two types, the development research is more firm-specific and therefore harder to share, whereas the generic research produces knowledge that is applicable in a wider range of firms. (Vonotras, 1994). The between-member spillovers in research joint ventures are thus at their largest in generic research (Katz, 1986).

A final important feature recognized in economic literature is the product market competition between cooperating firms that is measured by the degree of product differentiation. Lower differentiation prevents the competitive advantage gained by R&D work because rivals use more similar technologies and can benefit better from the cost-reducing knowledge. This means that the negative incentive effect in individual R&D work and the role of cooperation in fixing the incentives is magnified. (De Bondt, et al., 1992). However, more intense competition in the product market can lower the cooperative levels of R&D because an increasing part of their benefits accrue to consumers through lower competitive market prices (Katz, 1986). Since d'Aspremont-Jacquemin model employs a Cournot competition situation with only two duopoly firms, the results might be less attractive when the competitive situation is intensified (Vonotras, 1994).

In conclusion, the economic literature has given great attention to the complicated nature of knowledge spillovers. Therefore, it might be dangerous to simplify their nature in theoretical models to one single rate β like d'Aspremont and Jacquemin (1988) do. Asymmetries, nature of research and product market competition all affect the actual rate of spillovers and consequently the corresponding externalities. These main determinants of the welfare effects must be considered when applying the model to specific situations and policy decisions (d'Aspremont & Jacquemin, 1990).

3.4.2. Modeling R&D cooperation

The cooperative setting in d'Aspremont-Jacquemin model is very simplified which might lower its accuracy in demonstrating the real-life situations. The most significant deficiency is that the model considers spillovers as exogenous variables in the cost function that are the same in non-cooperative and cooperative settings. Hereby, it fails to embody many synergy effects of cooperation. (d'Aspremont & Jacquemin, 1990). In addition, there exists other benefits and costs of cooperation that must be considered outside theoretical modeling. These are covered in the section 4.

First, cooperating firms have common processes of transforming R&D investments into knowledge which means that they share information more comprehensively (Beath, et al., 1998). Most importantly, R&D cooperation eliminates the problems of asymmetric information that are a central issue in the competitive market transactions of technological knowledge. Since valuating the purchased information accurately is hard for the buyer, the dissemination of knowledge is often insufficient without cooperative sharing. (Katz, 1986). Depending on the organizational arrangement affecting the perfection of communication and the utilization of information, the spillovers rates in research joint ventures can become complete (d'Aspremont & Jacquemin, 1990). On the contrary, they remain only partial outside the ventures (Bernstein & Nadiri, 1989). More comprehensive information sharing is reached for example when firms conduct R&D collectively in shared facilities rather than each firm individually (Vonotras, 1994). This allows cooperating firms to obtain a certain level of cost reductions with fewer resources compared to no cooperation (Kamien, et al., 1992).

Second, R&D cooperation in research joint ventures allows firms to pool not only their research results but also research teams, technology and know-how which enhances their cost-reducing technologies (Suzumura, 1992). Therefore, cooperation allows higher cost reductions than non-cooperative activities (Poyako-Theotoky, 1999). In conclusion, d'Aspremont-Jacquemin – model fails to bring out the complete benefits of R&D cooperation by not allowing spillovers to increase when the firms cooperate. A model with endogenous spillovers would allow intensifying the cost-reducing benefits of R&D cooperation.

4. COMPARING R&D COOPERATION TO OTHER R&D POLICIES

The economic literature identifies three main policy measure to address the socially too low R&D incentives. In addition to R&D cooperation, there exists also tax policies and subsidies as well as ex post cooperation with intellectual property rights. In this section, I aim to give both additional aspects of the benefits and flaws of R&D cooperation as a policy measure and more perspective by comparing it to the alternative policies. However, my goal is not to make definitive conclusions about which policy is preferable and deeper comparative analysis needs to be conducted separately.

4.1. Opportunities and challenges of R&D cooperation

In addition to enabling larger cost reduction with fewer resources, R&D cooperation allows maintaining continuity as well as spreading and pooling risks (Douglas, 1990). Creating new technologies is a long-term project and require prolonged commitment and interaction between partners. In the long run, the speed of invention must be increasing to gain first-mover advantage in the market which naturally increases the risks the firms are taking. (Jacquemin, 1988). Therefore, sharing risks and conducting several less uncorrelated research paths brings significant benefits to the members of research joint ventures (Dasgupta & Maskin, 1987). Maintaining several independent research paths is crucial since the reduced duplication in R&D cooperation might also induce inflexibility and increase the possibility of dead-end research paths (Jacquemin, 1988).

An important remark concerning the intensified sharing of resources and information in research joint ventures is that the increased sharing is accompanied by increased competition (Choi, 1993). Cooperating firms are forced to endure this direct competition in the product market after the research stage (Grossman & Shapiro, 1987). This brings on the issue of partner selection and balanced contributions because some partners might be remarkably strengthened by the cooperation and impose a significantly increased threat on the other partners (Jacquemin, 1988). The intensified competition means that the benefits of R&D cooperation disperse quickly and the total profits in the industry decrease as market prices go down. Theoretically, it’s profitable for firms to form a research joint venture only if the possible gains from increasing efficiency are larger than the losses due to intensified competition. (Choi, 1993).

In this thesis, I examine the potential beneficial effects of R&D cooperation, but it would be misleading to think that cooperation is favorable whenever it induces more or more efficient R&D. To examine the overall welfare gains that research joint ventures enable, focusing on only equilibrium amounts of R&D is not enough. (Katz & Ordover, 1990). One aspect of research joint ventures is that it allows firms to get together and collude in the product market (Vonotras, 1994). This can bring on monopoly power and reduced competitive pressure to cooperating firms, causing them to reduce outputs in the product market. The fact that reduced output reduces the overall welfare in the economy would make the R&D cooperation an ineffective way to increase the R&D incentives. (Katz, 1986). Consequently, many authors conclude that the cooperative agreements should be allowed only for coordinating research activities and not cooperating in the production output (see e.g. Kamien, et al., 1992).

In addition to comparing non-cooperative and cooperative R&D efforts to the socially optimal ones, it is relevant to examine whether allowing firms to form research joint ventures in the first place is optimal from the social standpoint (Kamien, et al., 1992). Another aspect is the problem of stability in especially the cross-country cooperative agreements regarding for example diverse domestic regulations and the clash of corporate cultures (Jacquemin, 1988). However, these questions of optimality and feasibility are outside the focus area of this thesis and they must be analyzed separately.

4.2. Comparison to tax policies and subsidies

Tax policies as well as indirect and direct subsidies are government interventions used to increase R&D incentives (Katz & Ordover, 1990). However, the economic literature has highlighted several shortcomings that tax and subsidy policies possess compared to R&D cooperation that doesn't include government intervention. First, these policies fail to fix the problem of insufficient sharing of the R&D results. Therefore, taxes and subsidies are inefficient R&D enhancing policies especially when spillovers are weak but can work better with higher spillovers. (Spence, 1984). On the contrary, increased sharing of R&D results is one of the central benefits of R&D cooperation that is reached both with high and low spillovers (Katz, 1986).

Another shortcoming is that even if taxes and subsidies managed to raise R&D incentives, the resulting levels might in fact be distorted from the social optimum rather than corrected towards it (Dasgupta & Stiglitz, 1980). This raises the same problem of socially excessive R&D investments that explains why non-cooperative R&D levels in d'Aspremont-Jacquemin model exceed cooperative ones when spillovers are small. As discussed in section 3.3, socially excessive efforts are possible because competing firms might try to gain advantage over each other by investing more (Brander & Spencer, 1983). These excessive efforts are eliminated when firms cooperate in R&D since they coordinate the research agendas, reduce the duplication of efforts and have no need to compete in R&D (d'Aspremont & Jacquemin, 1988).

Tax and subsidy policies might generate moral hazard by giving firms incentives to engage in specious research project simply to accumulate subsidies (Katz & Ordover, 1990). The R&D cooperation evokes no moral hazard but cooperating firms might restrict R&D and output levels together due to the increased collective competitive force (Vonotras, 1994). It is hard to conclude which of these distortions is less harmful but at least the government must gather the funds for the subsidies somewhere and less public monetary support is disposable for other purposes. Indeed, collecting the revenues to pay the subsidies under different tax policies means transferring resources from one sector to another which creates deadweight losses. (Katz, 1986). These losses give rise to the criticism against subsidies based on government's right or ability to pick up the benefiters that gain the subsidies and the losers that are forced to fund them (Katz & Ordover, 1990).

4.3. Comparison to ex post cooperation

Like the R&D cooperation, the ex post cooperation is a way of fixing R&D incentives through the market forces with no government intervention which separates it from tax and subsidy policies. Supporting the ex post cooperation is possible for example by strengthening the intellectual property rights such as patents and licenses, or allowing more leeway for firms concerning the ex post cooperation arrangements. (Katz & Ordover, 1990).

Strong protection through the intellectual property right allows firms to limit the free flow of information to the potential buyers of rights hereby allowing increased revenues. This helps to fix the appropriability problem of R&D investments that individual firms face and increase

their incentives to conduct research. (Katz & Ordover, 1990). However, some authors argue that the efficacy of intellectual property rights depends greatly on the industry and the nature of technology it uses. Therefore, they may fail to entirely stop the knowledge from spilling over to the competitors. (see e.g. Jaffe, 1986). Research joint ventures can gather the beneficiaries of a new technology together to share the costs and benefits and alleviate this problem of free-riders. Nevertheless, the research joint ventures may fail to fix the entire problem as some firms may still decide to stay outside the venture to avoid the costs and instead take advantage of the knowledge produced by others. (Choi, 1993).

The intellectual property rights limiting the knowledge spillovers can be criticized because the spillovers force firms to share their R&D results and enable the socially sufficient sharing of successful innovations (Spence, 1984). In addition, the policies of stronger intellectual property rights may increase incentives to innovate in the first generation but may fail to motivate the follow-on innovations in the subsequent generations (Green & Scotchmer, 1990). Therefore, these policies limiting spillovers may decrease the aggregate productivity and the competitiveness of the local economy in the long term (Katz & Ordover, 1990).

Most importantly, intellectual property rights increase the knowledge dissemination prices over the marginal cost whereas the spillovers disseminate knowledge at the socially optimal level (Katz & Ordover, 1990). This means that even though the dissemination of R&D results continues, the intellectual property rights decrease the efficient sharing among firms (Spence, 1984). Research joint ventures allow not only costless sharing of R&D results among cooperating firms, but also long-term planning and commitment in research that offer crucial support for the economic growth (Jacquemin, 1988).

5. CONCLUSIONS

R&D cooperation in the research joint ventures has two important impacts on research. First, the cooperative efforts increase efficiency by eliminating the excessive duplication in firms' research agendas. Second, the cooperation increases the research incentives and amounts by internalizing the spillover benefits. The research joint ventures play an important role in increasing the R&D levels especially in industries with high spillover rates. The spillover rates are high when the product market competition is intense and the research on generic

technologies is important. In these industries, the individual incentives are biased from the social ones due to the low appropriability of the cost-reducing benefits. To best attain these beneficial effects, the existing technologies of cooperating firms need to be similar enough and the research must be generic enough to ensure applicability to all member firms. However, the R&D cooperation never attains the socially optimal level of R&D.

In addition, the research joint ventures generally enable more cost reductions with less resources due to the synergy benefits attained by increased information sharing and pooling all research resources. These synergies further intensify the benefits of R&D cooperation. Lastly, research joint ventures allow maintaining crucial continuity in research and pooling risks regarding new inventions and possible dead-end research paths. All these additional benefits are crucial regarding the individual firms' decisions of joining a research joint venture. Closer cooperation intensifies the competition among the cooperating firms and the overall gains from cooperation need to be more significant than the potential losses from the intensified competition.

All the R&D policies can succeed in fixing R&D incentives but the most important feature differentiating R&D cooperation from other policies is the additional improvements it offers for boosting R&D. The taxes and subsidies don't increase the incentives to share information and the intellectual property rights either limit the dissemination of knowledge or do it at socially excessive prices. Both policies may fail to promote continuity in innovation generation after generation. In addition, the subsidies are unfavorable due to the socially excessive investments, the moral hazard and the deadweight losses they promote. Therefore, the research joint ventures should be embraced for their ability to not only boost efficient sharing but also maintain continuity which ensures a continued increase of competitiveness.

In conclusion, my analysis shows that the research joint ventures perform well in boosting especially more effective innovation activities. Even though research joint ventures might conduct less research than individual firms in some situations, they bring about additional benefits that are crucial in promoting more productive research activities. Achieving these benefits is possible especially because of the carefully designed knowledge sharing structures. The support for long-term endeavors and risk-taking in creating new technologies makes the research joint ventures especially important in the central growth-boosting industries. Naturally the research joint ventures have potential threats as well, the most important one being the risks

of collusion and increased monopoly power among the cooperating firms.

The most important potential deficiency of my analysis is the simplified nature of d'Aspremont-Jacquemin –model. The model results might be exaggerated due to the examining only the basic research and allowing a limited intensity of competition among the cooperating firms. The theoretical models arguably become the more complex the closer they are to the real-life situations. However, I purposely chose a simple model to explain the effects of R&D cooperation through cost sharing as clearly as possible and I aim to ensure the applicability to the real-life by careful analysis supporting the model.

An aspect that my analysis doesn't cover is the best organizational structure for magnifying the benefits of research joint ventures. However, this subject is covered more in the literature of industrial organization and hereby is outside my focus on theoretical modeling of the incentive and other beneficial effects of the R&D cooperation. My comparative analysis of the other policy measures is also rather lightweight. Therefore, a great possibility for the future reviews is to carefully compare the policies' ability to boost effective innovative activities in different situations. In addition, my review covers the studies made close to the publication of d'Aspremont-Jacquemin –model. These studies offer great opportunities to develop the model's analysis further but more recent studies could offer different aspects and a closer relation to the current policies and research joint ventures.

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